

Description

POROUS MEDIA GAS BURNER

BACKGROUND OF INVENTION

[0001] The present invention relates to a porous media gas burner and methods for its use. In particular, the invention relates to a downhole gas burner used in formation heat treatment methods.

[0002] Combustion of gases in porous media is a process where a combustible gaseous mixture is injected into a porous matrix and is combusted within the porous matrix. Flames in porous media have higher burning velocities and leaner flammability limits than open flames. These effects are well known and are the consequence of excess enthalpy combustion. Essentially, heat that is generated in the combustion zone is transferred by radiation and conduction through the solid phase of the porous media to unburned gases. As a result, it is possible to achieve temperatures higher than the adiabatic flame temperature, and the increase in burning velocities can be significantly higher than the open flame laminar burning velocity for

the same mixture in an open space.

- [0003] Formation heat treatment is a process that is intended to improve hydrodynamic conditions around the wellbore. If formation temperatures reach an adequate level, blocking water may be vapourized, clay structure may be dehydrated, clay minerals may be partially destroyed, and microfractures may be induced in the formation near the wellbore. As a result, permeability around the wellbore may be significantly improved.
- [0004] It is known to use a downhole electrical heater in a formation heating method. The electrical heater is placed as close as possible to the target zone, and an inert gas such as nitrogen is co-injected through the annulus. The temperature of the injected gas may rise to as high as 800° C before entering the formation. However, this method involves large energy requirements which makes it cost-prohibitive, particularly with rising electrical energy costs.
- [0005] Combustion stimulation is a known technique to promote fluid production in a formation. A combustion front is initiated in a wellbore by means of a surface heater or burner and the front is propagated into the formation to a distance of up to about 6 meters. The formation in this zone is reduced to clean burnt sand, which is very fluid

permeable. However, the well casing is subjected to high temperatures, which is undesirable, and there is an elevated risk of explosions or well burnouts using this technique. It is necessary to maintain wellbore temperatures below 600°C in order to prevent damage to the liner, which limits the temperature which may be reached in the formation.

[0006] Therefore, there is a need in the art for a gas burner which may be used downhole in a formation heating process.

SUMMARY OF INVENTION

[0007] In one aspect, the invention may comprise a gas burner comprising a tubular housing adapted to operate in a pressurized environment, the housing defining an intake opening and a flue opening and comprising means for receiving a supply of fuel and air; a mixing zone where the fuel and air are mixed comprising a packed bed of porous media; an ignition zone comprising a packed bed of porous media, and a reaction zone comprising a packed bed of porous media; wherein the pore size of the mixing zone and the reaction zone is smaller than a minimum quenching distance of a fuel gas under standard conditions while the pore size of the ignition zone is larger than

the minimum quenching distance.

- [0008] In another aspect, the invention may comprise a downhole formation heating system for a wellbore including a well casing, the system comprising:
 - [0009] (a) a gas burner comprising a cylindrical housing defining an intake opening and a flue opening, the housing comprising means for receiving a supply of fuel and air; a mixing zone where the fuel and air are mixed; an ignition zone comprising an igniter and a reaction zone, each zone comprising a packed bed of porous media;
 - [0010] (b) an igniter for igniting the fuel and air within the gas burner;
 - [0011] (c) fuel and air supply tubing for delivering fuel and air to the burner; and
 - [0012] (d) means for delivering pressurized air or an inert gas in an annular space between the well casing and the fuel and air supply tubing.
- [0013] In another aspect, the invention may comprise a method of heat treating a formation comprising the steps of:
 - [0014] (a) inserting a gas burner comprising a cylindrical housing defining an intake opening and a flue opening, the housing comprising means for receiving a supply of fuel and air; a mixing zone where the fuel and air are mixed; an ig-

nition zone comprising an igniter and a reaction zone, each zone comprising a packed bed of porous media, into a wellbore;

- [0015] (b)injecting a fuel gas and air into the gas burner to create a combustible mixture and igniting the mixture to create a combustion front; and
- [0016] (c)causing the combustion front to travel out the gas burner and into the formation.

BRIEF DESCRIPTION OF DRAWINGS

- [0017] The invention will now be described by way of an exemplary embodiment with reference to the accompanying simplified, diagrammatic, not-to-scale drawings.
- [0018] Figure 1 is a schematic representation of one embodiment of the present invention.
- [0019] Figure 2 is a schematic representation of one embodiment of a formation heat treatment system.

DETAILED DESCRIPTION

- [0020] The present invention provides for a gas burner and methods of using a gas burner. When describing the present invention, all terms not defined herein have their common art-recognized meanings.
- [0021] In one embodiment, the invention comprises a gas burner

as shown schematically in Figure 1. The burner generally includes a body (10) which comprises a mixing zone (12), an ignition zone (14) and a reaction zone (16) where combustion will take place. The body may have any shape. In one embodiment, the body may be cylindrical or conical or have both cylindrical and conical sections. The body is preferably lined with a heat-refractory material such as a ceramic liner.

- [0022] As shown in Figure 1, the mixing zone (12) and ignition zone (14) comprise cylindrical portions of the tubular body (10) while the reaction zone (16) comprises a truncated conical portion, with an expanding diameter as the reactants flow away from the mixing zone of the inlet end. In one embodiment, the outlet end diameter of the reaction zone may be about twice that of the inlet end. The reaction zone may have a length about 4 to 5 times the diameter of the inlet end. The mixing and ignition zones may have a length approximately equal to their diameter.
- [0023] All three zones (12, 14, 16) may be packed with a porous media bed within the burner. The packed bed may comprise heat resistant ceramic spheres such as alumina beads or any other suitable particulate material to create a porous media bed for example, but not limited to, zirco-

nia-alumina composites, silicon carbide, or mullite (alumina-silicon dioxide). As shown in Figure 1, air or oxygen is provided to the burner in the mixing zone (12), along with the combustible gas. The gases mix in the mixing zone (12) and are ignited in the ignition zone (14) by means of an igniter (not shown), which may be a small open flame burner or a spark device. Once ignited, the flame front will be allowed to advance into the reaction zone (16).

- [0024] In one embodiment, the mixing zone (12) may be packed with small size particles so that the pore size in the mixing zone is smaller than the minimum quenching distance (MQD). The second section would the ignition zone (14) and may be packed with larger size particles so that the pore size is larger than the minimum quenching distance. The size and nature of the reaction zone (16) particles (pore size) would depend on energy and operational requirements, type of fuel gas and operating conditions and could be of either uniform size or a combination of sizes.
- [0025] As used herein, the phrase "minimum quenching distance" or "MQD" shall mean the minimum diameter or opening dimension through which a flame may travel under standard conditions. It may be observed that a flame in a mix-

ture within a flammable range will be extinguished if forced to propagate through a constriction. The walls of the constriction exert a repressive influence on the flame. A flame is quenched in a constriction because of two mechanisms which otherwise permit flame propagation: the diffusion of species, and the diffusion of heat. The walls of the constriction may extract heat and the smaller the restriction, the greater the surface to volume ratio will be. Similarly, the smaller the constriction, the greater the number of collisions of the active radical species with the wall, and the greater the number of these species which are destroyed. Accordingly, one skilled in the art will understand that increased temperature decreases the quenching distance and that quenching distance decreases as pressure increases.

[0026] MQD is a physical property of each fuel and may be determined in the laboratory or by using the criteria of Peclet number equal to 65. The Peclet number is a dimensionless parameter that is based on the specific heat, laminar burning velocity, density, thermal conductivity and thermal diffusivity of the gas mixture, however the heating of the porous media bed will affect the minimum quenching distance.

[0027] It is generally accepted that main driving factor in the combustion of gases in a porous media is heat recirculation through the porous media to preheat unburned reactants. This preheating of the reactants may permit combustion even if the pore size is smaller than the MQD of the porous media under standard conditions.

[0028] In one embodiment, the burner (10) is adapted to operate in a pressurized environment. The body of the burner (10) is designed to withstand the desired pressure. This provides the opportunity to integrate the burner in the middle of a process stream, so that exhaust gases may be recovered at pressure for further treatment, separation or other downstream processes. It may allow use in subterranean hydrocarbon formations as will be subsequently described. The porosity of the packed bed may be controlled for specific applications. In one embodiment, the packed bed in the mixing zone and the reaction zone has a pore size smaller than the minimum quenching distance, while the ignition zone pore size may be larger than the minimum quenching distance. The pore size, combustible mixture flux, concentration of fuel gas in oxidant (air), type of fuel and shape of the burner may be varied to permit and optimize the process in a pressurized environ-

ment. A person skilled in the art may determine these matters with minimal and routine experimentation. The main effect of operating pressure in the gas burner is a reduction in the combustion front velocity. Maximum temperatures attainable when operating at elevated pressures are generally lower than those temperatures observed for the same gas mixtures and fluxes at atmospheric pressure. While the effect of pore size is almost negligible at atmospheric operating pressure, as the operating pressure is increased, the velocity of the combustion front increases as the pore size decreases. At elevated operating pressures, burning velocities appear to increase as the inlet gas velocity increases. Additionally, burning velocities appear to increase as the fuel gas concentration is decreased.

- [0029] The relatively smaller pore size of the mixing and the reaction zone promotes mixing of the reactants and pre-heating of the reactants due to heat transfer from the solid phase to the gas phase. The relatively larger pore size of the ignition zone allows easier ignition of the reactants and propagation of the flame into the reaction zone.
- [0030] The gas burner (10) may be used as a downhole gas burner to be used in a formation heating method. Gener-

ally, the formation heating method may comprise two stages. In a first stage, the burner is placed in the wellbore at the level of the formation by means of coiled tubing or the like. The tubing also provides the means by which a combustible mixture is provided to the burner. The combustible mixture may be a lean mixture of natural gas and air which is below the flammability limits of natural gas at atmospheric pressure. The mixture may sustain a combustion front within the burner which expels hot flue gases into the formation. If desired, the combustion front may be controlled to travel outward from the burner into the formation. The combustion front is controlled by increasing or decreasing the fuel gas flux, changing the concentration of fuel gas in the mixture fuel-air (oxidant) and by using different particle size or a combination of particle sizes in the reaction zone. These variable elements may be varied either singly or in combination.

- [0031] Depending on the composition of the formation hydrocarbons, the amount of oxygen in the flue gas and the flue gas temperature, some oxidation/combustion reactions may start to take place in the formation at the same time as gas combustion is occurring in the burner. Once the combustion front leaves the burner, it is preferred to in-

crease the concentration of the fuel, so that the temperature of the reaction front increases. This may be done safely because the temperature in the burner and the wellbore will not be high enough to facilitate or sustain combustion. In other words, the burner becomes a flame arrester once the combustion front travels outward into the formation.

- [0032] The burner described herein may be used as a downhole burner in alternative methods. As described above, the burner may be used in well stimulation method where blocking water is vapourized, clays may be partially destroyed, asphaltenic deposits may be burned and microfractures in the formation may be propagated. In another example, the downhole gas burner may be used in a downhole steam generation method for cyclic or continuous steam injection in deep heavy oil wells. In another example, the downhole gas burner may be used in a high pressure air injection technique, where combustion is initiated in the formation and air is then continuously injected into the producing layer. The combustion of in-place oil may provide thermal and gas drive to the oil reservoir.
- [0033] In one embodiment, with reference to Figure 2, a down-

hole burner (10) is positioned near the producing formation (20) by means of continuous or coiled tubing (22) and anchored to the well casing by means of an anchor (24). Air is injected through the tubing (22) and a combustible gas such as natural gas is injected through a separate tubing (26) to the burner. Air or an inert gas such as nitrogen may be injected in the annulus between the well casing and the tubing (22). The burner has a mixing zone (120), an ignition zone (122) and a reaction zone (124), each packed with a suitable porous media. As described above, in a preferred embodiment, the particle size or minimum quenching distances in each zone may be varied. The combustion front (126) will be established in the reaction zone (124) and move outward into the formation. At the same time, hot flue gases (128) are pushed outward into the formation.

- [0034] In each case, the ignition and combustion downhole and/or in the formation may be initiated using a lean combustible mixture, which may include waste gases. The lean mixture reduces the risk of explosive mixtures accumulating in the system.
- [0035] As will be apparent to those skilled in the art, various modifications, adaptations and variations of the foregoing

specific disclosure can be made without departing from the scope of the invention claimed herein. The various features and elements of the described invention may be combined in a manner different from the combinations described or claimed herein, without departing from the scope of the invention.

[0036] EXAMPLES

[0037] The following examples describe specific embodiments which are exemplary of the present invention. They are not intended to limit the claimed invention.

[0038] Example 1Porous Media

[0039] In one embodiment, the porous media comprises relatively uniform alumina spheres (90% alumina and 10% silica) having the following physical and hydrodynamic properties:

[0040] (a)specific heat capacity at 20°C, J/kgK 920

[0041] (b)thermal conductivity at 20°C, W/mK 16.7

[0042] (c)Density, kg/m³ 3, 600

[0043] (d)diameter, m 5.6 E-3 to 2.9 E-3

[0044] (e)Porosity, fraction 0.383

[0045] (f)Pore size, m 2.31 E-3 to 1.18 E-3

[0046] (g)Permeability (Carman-Kozeny equation) m^2 2.544 E-8
to 6.625 E-9